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PARADICHLOROBENZENE EXPERIMENTS IN THE SOUTH FOR PEACH-BORER CONTROL

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INTRODUCTION

The peach borer (*Aegeria exitiosa* Say) [1] has been one of the most serious insect pests attacking peach trees east of the Rocky Mountains since the time of the early settlers, and until recent years no satisfactory control for it was known. Previous to Blakeslee's [2] discovery of the value of paradichlorobenzene for peach-borer control, the laborious and only partially effective method of removing the borers with a worming knife in the fall of the year was resorted to by most peach growers. Since the appearance of Blakeslee's report in 1919, a great deal of experimental work with paradichlorobenzene for peach-borer control has been conducted in different parts of the country, and its use by peach growers has increased tremendously during the last few years. Peterson [3] has given a very complete report on the use of paradichlorobenzene and other materials for the control of the peach borer in New Jersey. His publication also contains an excellent bibliography of the most important papers on the peach borer. The authors [4] have issued a report of progress on their prardichlorobenzene studies in Georgia during the 1921–22 season, and detailed directions for the use of the chemical against the peach borer were given in a bulletin by Quaintance [5] in 1921.

[1] Order Lepidoptera, family Aegeriidae.

[2] BLAKESLEE, E. B. USE OF TOXIC GASES AS A POSSIBLE MEANS OF CONTROL OF THE PEACH-TREE BORER. U. S. Dept. Agr. Bul. 796, 23 p, illus. 1919.

[3] PETERSON, ALVAH. THE PEACH BORER IN NEW JERSEY (WITH NOTES ON SIMILAR PESTS). New Jersey Agr. Expt. Sta. Bul. 391, 143 p., illus. 1922.

[4] SNAPP, OLIVER I., and ALDEN, CHARLES H. FURTHER STUDIES WITH PARADICHLOROBENZENE FOR PEACH-BORER CONTROL, WITH SPECIAL REFERENCE TO ITS USE ON YOUNG PEACH TREES. U. S. Dept. Agr. Bul. 1169, 18 p., illus. 1923.

[5] QUAINTANCE, A. L. THE PEACH BORER. HOW TO PREVENT OR LESSEN ITS RAVAGES. THE PARADICHLOROBENZENE TREATMENT. U. S. Dept. Agr. Farmers' Bul. 1246, 14 p., illus. 1921.

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This bulletin gives a comprehensive report of paradichlorobenzene experiments, with conclusions and recommendations, which were conducted in the Georgia peach belt from 1922 to 1926; it also makes reference to the work conducted in 1921. Six years was considered the minimum tree age for the safe use of paradichlorobenzene when these experiments were started; consequently, most of the experiments have been confined to peach trees ranging in age from 1 to 5 years, in an effort to extend the use of the chemical to young trees with safety. The results of the experiments herein reported show that paradichlorobenzene is safe for use in the South on peach trees 5 years of age and older, and fairly safe on 4-year-old trees, but unsafe in this latitude on 1, 2, and 3 year old trees, especially when weather conditions cause a rapid evaporation of the crystals, or retard the normal diffusion of the gas through the soil, resulting in an abnormal gas concentration around the tree trunk at and below the ring of crystals.

EMERGENCE OF PEACH-BORER ADULTS IN GEORGIA

Gas for peach-borer control is most effective in the fall of the year at the close of the oviposition period of the insect. As a part of the paradichlorobenzene application experiments in the Georgia peach belt, 245 peach-borer cocoons were collected from peach trees near Fort Valley during August and September, 1923, in order to obtain data on the emergence of peach-borer adults. Of these cocoons, 192 contained either peach-borer larvae or pupae, and 53 were empty, the adults having issued from the empty cocoons some time previous to the date on which they were collected. From the cocoons containing larvae or pupae, 25.8 per cent of the moths emerged during August and 74.2 per cent during September, the last date of emergence for the females being September 24, and for the males September 28. Starnes,[6] in his work on the life history of the peach borer in Georgia, shows that in 1904 there was a moth emergence of 15.9 per cent in August and 84.1 per cent in September, and that in 1905 there was a moth emergence of 8.3 per cent in August and 91.7 per cent in September. The greater part of the moth emergence in Georgia, therefore, occurs during September and practically all of the egg deposition and hatching is over before the time for the applications of paradichlorobenzene in October.

CHEMICALS TESTED FOR PEACH-BORER CONTROL

In addition to paradichlorobenzene, both in the sublimed and unsublimed form, orthodichlorobenzene, paratoluidine, and calcium cyanide were tested for the control of the peach borer and for data on tree injury. These chemicals were all applied like paradichlorobenzene, except that the calcium cyanide used in 1925 was placed in a shallow trench around the trees and lightly covered with soil.

Orthodichlorobenzene, which is a liquid, was used during the fall of 1922 at Byron, Ga., and at Winchester, Ga., on 5 and 7 year old trees. Three-fourths and 1 ounce doses were used, and were allowed to remain around the trees for six weeks. This material proved to be an effective larvicide; but it caused very severe injury to the trees, finally killing many of the 5-year-old trees and a few of those that were 7 years old.

[6] STARNES, HUGH N. THE PEACH TREE BORER. Georgia Exp. Sta. Bul. 73, pp. 147–190, illus. 1906.

Paratoluidine, which is a nearly colorless solid of thin, flat crystals, was used on a few 2, 3, and 11 year old trees at Fort Valley and at Winchester during the 1922–23 season. No tree injury resulted from ¼, ½, and ¾ ounce doses, but the chemical failed to control the borers in the 11-year-old trees, probably because it was not applied until November. The cost of this material at the present time renders its use for borer control impracticable.

Calcium cyanide, in both the dust and granular form, was used in the spring of 1924 on a few 6-year-old trees at Lee Pope, Ga. Final examinations showed no injury to the trees from 2 ounces of either kind; however, no information was obtained on its effectiveness as a larvicide on account of the absence of borers in the trees. During the fall of 1925 rather extensive tests were made with this material at Fort Valley around 1, 2, 3, and 4 year old peach trees. Forty-four larvae were taken from the trees treated with from 1-ounce to 3-ounce doses exposed from 4 to 8 days. Thirty-five of these larvae were dead, showing a mortality of 79.5 per cent. There were 11 live borers in the untreated trees. No tree injury was noted at the time of examination for borer mortality, but later in the fall discoloration of the cambium was noted on some of the trees that were treated with the 2 and 3 ounce doses. Examinations made of the trees the following spring showed these results: The 1-year-old trees treated with the ½ and 1-ounce doses for 4 days showed no injury. Of the 2-year-old trees exposed to the gas for 4 days, 1 was dead and 4 were uninjured from the ½-ounce dose; 1 was injured and 4 uninjured from the 1-ounce dose; and 1 was dead and 4 uninjured from the 1½-ounce dose. The 3-year-old trees treated for 4 days with 1 ounce showed no injury; however, 2 ounces for the same length of time injured one of five 3-year-old trees. Of the 4-year-old trees exposed to the gas for 4 days, 1 was injured and 4 were uninjured from both the 1-ounce and 2-ounce doses, and all 5 were severely injured from the 3-ounce dose. Of the 4-year-old trees exposed to the gas for 8 days, 1 out of 4 was injured from 1 ounce; 3 out of 4 were injured from 1½ ounces; and 4 out of 4 were injured from the 2-ounce dose.

Table 1 gives a summary of the results that were obtained in testing the several chemicals, except paradichlorobenzene, for peach-borer control in Georgia.

TABLE 1.—*Results obtained from orthodichlorobenzene, paratoluidine, and calcium cyanide applied to peach trees for observation on tree injury and peach-borer mortality; Georgia, 1922–1925*

Material[1]	Quantity	Date applied	Date examined	Length of exposure	Age of trees	Number of trees	Larvae killed	Injury to trees at time of final examination
	Oz.	1922	1922	*Days*	*Years*		*P. ct.*	
Orthodichlorobenzene	¾	Oct. 11	Nov. 21	42	5	10	75	3 dead, 7 severely injured.
Do	1	...do	...do	42	5	10	100	1 dead, 7 dying, 2 severely injured.
Do	¾	Oct. 13	Nov. 23	42	7	25	100	4 dead, 1 dying, 20 with cambium injured.
Do	2	...do	...do	42	7	25	(2)	4 dead, 3 dying, 16 with cambium injured, 2 normal.
Control			Oct. 21		5,7	20	(3)	No injury.

[1] These chemicals were all applied like paradichlorobenzene, except that the calcium cyanide used in 1925 was placed in a shallow trench around the trees and lightly covered with soil.

[2] No larvae.

[3] 43 live larvae.

TABLE 1.—*Results obtained from orthodichlorobenzene, paratoluidine, and calcium cyanide applied to peach trees for observation on tree injury and peach-borer mortality; Georgia, 1922–1925*—Continued

Material	Quantity	Date applied	Date examined	Length of exposure	Age of trees	Number of trees	Larvae killed	Injury to trees at time of final examination
	Oz.	1922	1923	*Days*	*Years*		*P. ct.*	
Paratoluidine	½	Nov. 10	Apr. 23	(1)	2	3	(1)	Do.
Do	¾	...do	...do	(1)	2	3	(1)	Do.
Do	½	...do	...do	(1)	3	3	(1)	Do.
Do	¾	...do	...do	(1)	3	3	(1)	Do.
Do	¼	Nov. 13	Apr. 24	(1)	10	3	0	Do.
Do	½	...do	...do	(1)	10	3	25	Do.
Do	¾	...do	...do	(1)	10	3	0	Do.
Control			...do		10	3	(2)	Do.
		1924	1924					
Calcium cyanide (dust)	2	Apr. 1		7–35	6	5	(3)	Do.
Calcium cyanide (granular).	2	...do		7–35	6	5	(3)	Do.
Control			May 8		6	5	(3)	Do.
		1925	1925					
Calcium cyanide (dust)	½	Oct. 15	Oct. 19	4	1	3	(3)	Do.
Calcium cyanide (granular).	½	...do	...do	4	1	2	(3)	Do.
Calcium cyanide (dust)	1	...do	...do	4	1	3	(3)	Do.
Calcium cyanide (granular).	1	...do	...do	4	1	2	(3)	Do.
Calcium cyanide (dust)	½	...do	...do	4	2	3	(3)	1 dead, 2 uninjured.
Calcium cyanide (granular).	½	...do	...do	4	2	2	(3)	No injury.
Calcium cyanide (dust)	1	...do	...do	4	2	3	(3)	Do.
Calcium cyanide (granular).	1	...do	...do	4	2	2	(3)	Cambium injured on 1 tree; 1 uninjured.
Calcium cyanide (dust)	1½	...do	...do	4	2	3	(3)	1 dead, 2 uninjured.
Calcium cyanide (granular).	1½	...do	...do	4	2	2	(3)	No injury.
Calcium cyanide (dust)	1	...do	...do	4	3	3	(3)	Do.
Calcium cyanide (granular).	1	...do	...do	4	3	2	(3)	Do.
Calcium cyanide (dust)	2	...do	...do	4	3	3	100	1 slightly injured, 2 uninjured.
Calcium cyanide (granular).	2	...do	...do	4	3	2	(3)	No injury.
Calcium cyanide (dust)	1	...do	...do	4	4	3	50	1 with cambium killed in spots, 2 uninjured.
Calcium cyanide (granular).	1	...do	...do	4	4	2	(3)	No injury.
Calcium cyanide (dust)	2	...do	...do	4	4	3	100	1 with cambium killed in spots, 2 uninjured.
Calcium cyanide (granular).	2	...do	...do	4	4	2	(3)	No injury.
Calcium cyanide (dust)	3	...do	...do	4	4	3	(3)	3 trees with cambium severely injured.
Calcium cyanide (granular).	3	...do	...do	4	4	2	100	2 trees with cambium severely injured.
Control			...do		1–4	20	(3)	No injury.
Calcium cyanide (dust)	1	Oct. 20	Oct. 28	8	4	3	62.5	1 with cambium killed in spots, 1 uninjured.
Calcium cyanide (granular).	1	...do	...do	8	4	3	100	No injury; 1 missing.
Calcium cyanide (dust)	1½	...do	...do	8	4	2	66.6	1 with cambium killed in spots, 1 missing.
Calcium cyanide (granular).	1½	...do	...do	8	4	3	93.3	2 with cambium killed in spots, 1 uninjured.
Calcium cyanide (dust)	2	...do	...do	8	4	2	50	2 with cambium killed in spots.
Calcium cyanide (granular).	2	...do	...do	8	4	3	75	2 with cambium killed in spots, 1 missing.
Control			...do		4	1	(4)	No injury.

[1] No larvae.
[2] Over winter.
[3] Not examined.
[4] 10 live larvae.
[5] 4 live larvae.
[6] 7 live larvae.

PARADICHLOROBENZENE

Paradichlorobenzene, $C_6H_4Cl_2$, is a shiny white crystalline solid at ordinary temperatures. It is insoluble in water, has a boiling point of 172° C., a melting point of 53° C., and a low vapor pressure at ordinary temperatures, being about 10 times as great at 100° F. as at 50° F. It has a specific gravity of 1.268, and a molecular weight of 146.96. The gas is heavier than air, and nontoxic to man, but toxic to most insects.

The rate of evaporation of paradichlorobenzene crystals in the soil is dependent upon temperature, moisture, aeration, and the size of the crystals. Only unadulterated paradichlorobenzene of about the fineness of granulated sugar should be used, in order to insure evaporation of the desired rapidity and uniformity. Pure paradichlorobenzene that will pass a sieve having 10 meshes to the linear inch has been found very satisfactory for peach-borer control.

Before paradichlorobenzene is applied, all grass, stones, and trash should be removed from around the tree for a radius of about a foot, and the soil surface should be made smooth with the back of a shovel. The crystals should then be distributed in a continuous band on the soil around the tree. This band of crystals should be 1½ inches wide, and about 1½ inches from the tree trunk, and should be above the point where the topmost borer is working in the tree. The crystals are then carefully covered with a shovelful of clean soil, after which several more shovelfuls are added and packed to form a cone around the tree. (Figs. 1 and 2.)

The ¾-ounce dose of paradichlorobenzene should be used for 4 and 5 year old trees, and the mounds and unspent crystals removed four weeks after the application. For trees 6 years of age and older the 1-ounce dose should be used, and as an added precaution against tree injury the mounds and unspent crystals should be removed six weeks after the application to trees of those ages. Paradichlorobenzene should not be used on 1, 2, and 3 year old trees in the South, as under some weather conditions serious tree injury may result if the chemical is applied to trees of those ages. A tree is considered 4 years old when it has been in the ground for four full growing seasons.

Paradichlorobenzene should be applied in central Georgia between October 10 and 15; in northern Georgia between October 1 and 5; in the mountainous section of northeastern Georgia between September 25 and October 1; and in southern Georgia between October 15 and 20. The chemical should be applied on the same dates in similar latitudes of other Southern States. Effective results can not be obtained unless the material is applied on or close to the above dates, and according to the directions. (Figs. 1 and 2.) Poor results will be obtained if the material is applied as shown in Figure 3. If, for an unavoidable reason, the usual fall application can not be made, the chemical may be put out in the spring about April 1; however, spring applications are not as effective as those made in the fall, and furthermore they allow the borers to work unmolested in the trees more or less throughout the winter.

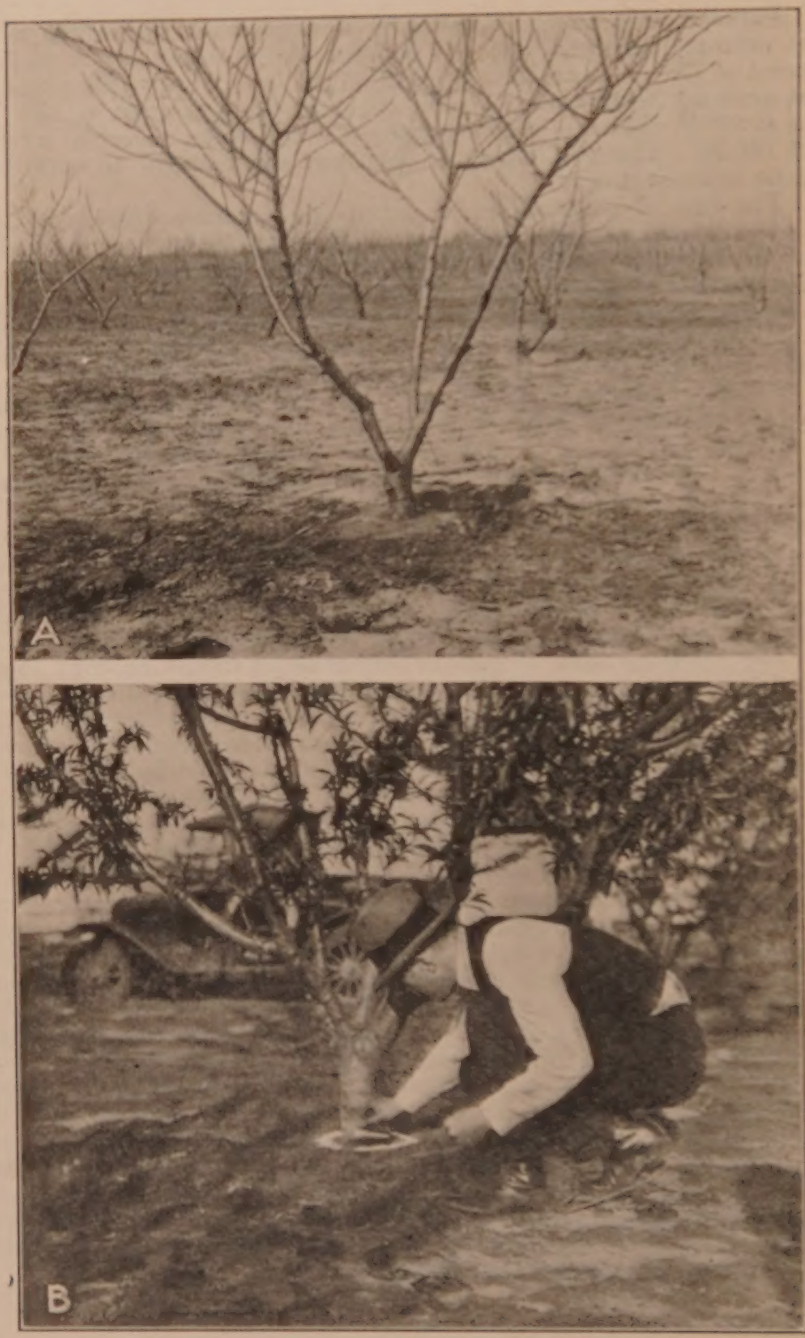

FIG. 1.—A, Soil around peach tree made ready for paradichlorobenzene treatment; B, applying paradichlorobenzene with a handy cone-shaped container that holds exactly 1 ounce

FIG. 2.—A, The ring of crystals should be about 1½ inches wide and 1½ inches from the tree trunk; B, several shovelfuls of soil should be placed on top of the ring of crystals and packed gently with the back of a shovel

FIG. 3.—Incorrect methods of applying paradichlorobenzene: A, The mound should have been placed around this tree where borers are working so that the crystals could be placed above them; B, when the chemical is placed against the trunk as shown severe injury to the tree may result; C, in this case the ring of crystals is too far from the tree trunk for effective results

PARADICHLOROBENZENE EXPERIMENTS IN ORCHARDS, 1921–1926

A large number of paradichlorobenzene experiments were conducted in Georgia peach orchards from 1921 to 1926. Table 2 gives the location of these orchards, the year they were used, the age of trees, type of soil, and condition of trees at the time of treatment.

TABLE 2.—*Location of paradichlorobenzene experimental orchards, age of trees, year used, type of soil, and condition of trees at time of application; Georgia, 1921–1925*

Location of orchard	Age of trees (years)	Year used	Type of soil [1]	Condition of trees at time of application
Marshallville	1 and 2	1921	Red sandy loam	Good.
Fort Valley	3	1921	do	Do.
Marshallville	4	1921	Sandy loam	Fair.
Wesley Chapel	5 and 6	1921	Gray sandy loam	Do.
Marshallville	1, 2, 3, and 7	1922	Red sandy loam	Good.
Fort Valley	4 and 10	1922	do	Do.
Byron	5	1922	Sandy loam	Do.
Fort Valley	1, 3, 5, 7, and 11	1923	do	Do.
Marshallville	2	1923	do	Do.
Zenith	4	1923	do	Do.
Lee Pope	6	1923	do	Do.
Fort Valley	1, 2, 4, 5, and 6	1924	do	Do.
Marshallville	3	1924	do	Do.
Zenith	10	1924	do	Do.
Fort Valley	1, 2, 3, and 7	1925	do	Do.
Marshallville	4	1925	do	Do.
Montezuma	5 and 6	1925	do	Do.

[1] Drainage was excellent in all the orchards.

The experiments were conducted in 35 different orchards, the trees in which ranged in age from 1 to 11 years, although in most cases trees from 1 to 6 years of age were used. Most of the trees were in good condition when the experiments were started, although a few showed only fair condition. The 3-year-old orchard used at Fort Valley in 1921 was used also for each succeeding year including 1925, hence paradichlorobenzene was used around the same trees during five consecutive years. No discernible tree injury resulted in this period and the peach borer was almost completely eradicated. Fort Valley has been the location of most of the experiments. Others were conducted at or in the vicinity of near-by towns.

Summaries of the results of paradichlorobenzene experiments in orchards during the four seasons extending from the fall of 1922 to the spring of 1926, together with the dosages and exposures used for trees of each age, are given in Tables 3 and 4. Table 3 presents the results of the experiments with reference to tree injury noted at the final examination, and Table 4 shows the mortality of borers found in the trees that were examined for borers.

TABLE 3.—*Tree injury resulting from use of paradichlorobenzene in experiments for peach-borer control, 1922 to 1926, inclusive; central Georgia*

SEASON OF 1922–23

Age of trees in years	Time of application [1]	Length of exposure in weeks	One-fourth ounce dose		One-half ounce dose		Three-fourths ounce dose		One ounce dose		Number of control trees
			Number of trees	Tree injury at final examination	Number of trees	Tree injury at final examination	Number of trees	Tree injury at final examination	Number of trees	Tree injury at final examination	
1	Oct. 10–15	3			10	None	10	None			10
1	do	4			10	do	10	do			
1	do	6			10	do					
2	do	3			10	do	10	None	10	1 tree with bark layers flecked.	
2	do	4			10	do	10	1 tree with bark layers flecked.	10	do	
2	do	6			10	do	10	2 trees with bark layers flecked.	10	1 tree had cambium injured, 3 had bark flecks.	15
2	do	(?)			10	do	10	1 tree with bark layers flecked.	10	3 trees with severe bark layer flecking.	
3	do	3			10	do	10	None	10	None	
3	do	4			10	do	10	do	10	do	15
3	do	6			10	do	10	do	10	do	
3	do	(?)			10	do	10	do	10	do	
4	do	3					10	do	10	do	
4	do	4					10	do	10	do	10
4	do	6					10	do	10	do	
4	do	(?)					10	do	10	do	
5	do	3					10	do	10	do	
5	do	4					10	do	10	do	10
5	do	6					10	do	10	do	
5	do	(?)					10	do	10	do	
7	do	6							[2] 6	do	10
7	do	6							40	do	7
10	Apr. 4	6									

SEASON OF 1923–24

1	Oct. 10–15	4			20	None	20	None			10
2	do	4			20	Slight flecking on 1; severe flecking on 12.	20	Slight flecking on 2; severe flecking on 9.			10
3	do	4			30	None, 3; slight, 2; severe, 20; cambium, 5.	30	None, 1; slight 7; severe, 14; dead, 8.	20	Slight, 3; severe, 14; dead, 3.	10

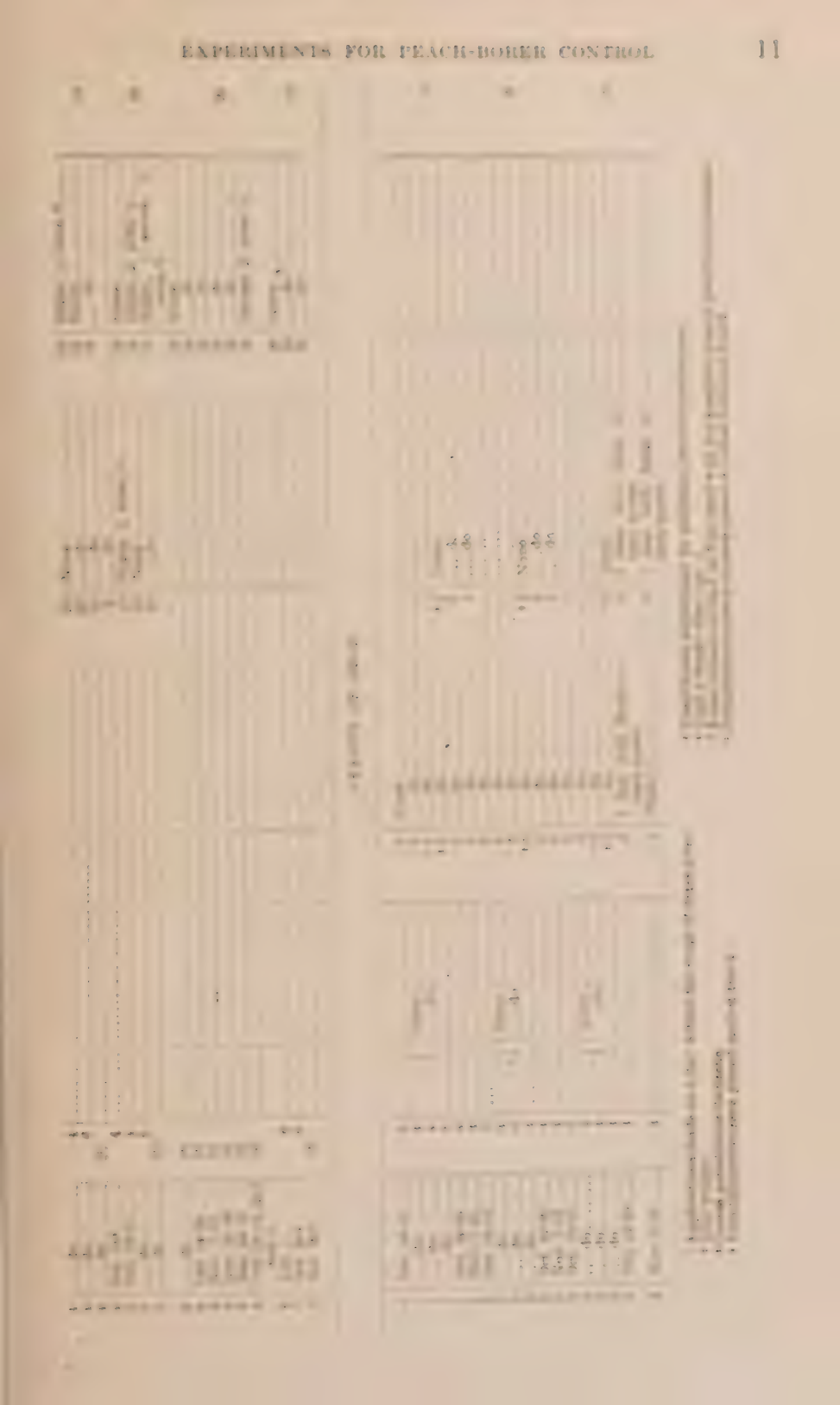

TABLE 3.—*Tree injury resulting from use of paradichlorobenzene in experiments for peach-borer control, 1923 to 1927, [illegible], Georgia*—Continued

Age of trees in years	Date of application	Length [illegible] to season	One-fourth ounce dose		One-half ounce dose		Three-fourths ounce dose		One ounce dose		Number of [illegible] trees
			Number of trees	Tree injury at final examination	Number of trees	Tree injury at final examination	Number of trees	Tree injury at final examination	Number of trees	Tree injury at final examination	
4	Oct. 29–31	5					10	None			
4	do	[illegible]					10	do			
4	Oct. 24–25	4					10	do			
4	Oct. 28–29	4					10	do			
4	do	[illegible]					10	do			
4	Oct. 24–25	4					10	do			
4	Oct. 28–29	4							10	None	
10	do	4							10	do	
10	do	4							10	do	
10	do	[illegible]							10	do	
10	Oct. 24–25	4									

SEASON OF 1926–27

1	Oct. 29–31	4	4	None	7	None					
2	do	4			10	2 borer cells; Stocks 14 feet apart					
3	do	4			10	2 borer cells; Stocks 16 feet apart					
4	do	4					8	1 very slight, 2 with gummosis, 5 none; Stocks 16 feet apart			
5	do	4					10	None			
6	do	4							10	None	
7	do	4									

[1] Over winter.

[2] One leaf [illegible] [illegible] paradichlorobenzene [illegible]

TABLE 4.—*Mortality of peach borers as [illegible] experiment in northern Ga., 1922 to 1925, inclusive*

SEASON OF 1922-23

Date of dose in ounces	Age of trees	Time of application [illegible]	Time of exposure	Number of trees	Larvae			
					Found	Mature-fed	Indeterminate	Percentage killed
	Years		*Weeks*					
[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0
[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]
Check	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SEASON OF 1923-24

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]

1921-22 EXPERIMENTS

The results of the paradichlorobenzene experiments conducted during the season of 1921-22 have been presented by the authors in United States Department of Agriculture Bulletin No. 1169, and therefore no detailed account will be given of that work in this bulletin. That season was very favorable for the use of paradichlorobenzene, as revealed by observations, and no serious tree injury was noted on any of the trees used, except a few brown lesions in the outer bark layers of some trees at a point opposite the ring of crystals. The regular fall applications, commencing October 10, gave a borer mortality of from 95 to 100 per cent. Poor results were obtained with large dosages for short exposures, and very fair results with small dosages applied at the regular time for long exposures. Very poor results were obtained when the crystals were applied during late November and early December.

1922-23 EXPERIMENTS

Peach trees 1, 2, 3, 4, 5, 7, and 10 years old were used for the paradichlorobenzene experiments during the 1922-23 season. One observation was made for borer mortality, and three for tree injury, the final one of which was about 10 months after the material was applied. Summaries of results of the 1922-23 paradichlorobenzene experiments are included in Tables 3 and 4.

The 1-year-old trees showed no injury from the ½ or ¾ ounce dose at any of the examinations for tree injury. No data were obtained on borer mortality in these trees, as there were no borers present, even in the control or untreated trees.

At the time of the final examination none of the 2-year-old trees showed any signs of injury from the ½-ounce dose of paradichlorobenzene which was exposed to the trees for a period varying from 3 weeks to over winter. The 2-year-old trees treated with the ¾-ounce dose showed no injury for the 3 weeks' exposure, 1 tree showed flecked bark layers from the 4 weeks' exposure (fig. 4), 2 trees had flecked bark layers from a 6 weeks' exposure, and 1 showed the same injury from the overwinter exposure. The 2-year-old trees treated with the 1-ounce dose showed 1 tree with bark layers flecked from the 3 weeks' exposure, 1 with flecked bark layers from the 4 weeks' exposure, 3 with flecked bark layers and 1 with the cambium slightly injured from the 6 weeks' exposure, and 3 with severely flecked bark layers from the overwinter exposure. None of the injury was severe enough to kill any of the trees.

The condition of the injured trees in the 2-year-old orchard at the fall and spring examinations was somewhat different from that found at the time of the final examination. Of the 10 trees treated with the ½-ounce dose for 6 weeks, 5 showed moderately flecked bark layers at the fall examination. At the spring examination only 2 of these trees showed moderately flecked bark layers. Of the 10 trees treated with the ¾ ounce dose for 6 weeks, 4 showed slight flecking and 1 showed moderate flecking of the bark layers at the fall examination; whereas at the spring examination only 2 of these trees showed moderate flecking of the bark layers. Of the 10 trees treated with the ¾-ounce dose for an overwinter exposure, 1 showed slight and 3 showed moderate flecking of the bark layers at the spring examination. Of the 10 trees treated with the 1-ounce dose for 4 weeks,

4 showed very slight and 3 slight flecking of the bark layers, and 1 showed a flecked cambium at the fall examination. At the spring examination 2 of these trees showed slight and 8 moderate flecking of the bark layers. Of the 10 trees treated with the 1-ounce dose for 6 weeks, 4 showed slightly flecked bark layers and 2 showed flecked cambiums at the fall examination; whereas at the spring examination 5 showed moderate flecking of the bark layers. Of the 10 trees

FIG. 4.—Flecked condition of the bark layers of a [illegible] peach tree [illegible] of a ½-ounce dose of paradichlorobenzene for four years.

treated with the 1-ounce dose for an overwinter exposure, 4 showed an injured cambium, and 1 moderate flecking of the bark layers, at the spring examination.

Only one borer was found in the 2-year-old trees. This individual was three-fourths grown, and was killed by a ½-ounce dose in three weeks. There were no borers in the untreated trees.

The 3-year-old trees showed no injury from paradichlorobenzene at any of the three examinations. Borer mortality was as follows: One one-fourth grown and 3 half-grown dead where exposed to a

½-ounce dose for 2 weeks; 1 half-grown dead where exposed to a ½-ounce dose for 4 weeks; 1 less than one-fourth grown and 1 one-fourth grown dead, where exposed to a ¼-ounce dose for 2 weeks. No borers were found in any of the trees treated with the other dosages and exposures, and none was found in the painted or untreated trees.

The 4-year-old trees showed no injury from paradichlorobenzene at any of the three examinations. No borers were found in any of the treated trees that were examined for borer mortality. Seven live borers were found in the untreated trees.

The 5-year-old trees showed no injury from paradichlorobenzene at any of the three examinations. Borer mortality was as follows: Two half-grown dead, and 1 half-grown stupefied in trees treated with the ¼-ounce dose for 4 weeks. No borer observations were made on the remainder of the treated trees. There were 43 live borers and 1 dead borer in the 5-year-old control or untreated trees.

The 7-year-old trees showed no injury from either the usual granulated or coarse grade of paradichlorobenzene at any of the three examinations. No borers were found in either the treated or untreated 7-year-old trees.

The 10-year-old trees showed no injury from paradichlorobenzene at either of the two examinations. Borer mortality was as follows: Three one-fourth grown, 34 one-half grown, 45 three-fourths grown, and 7 were three-fourths grown, dead; 5 one-half grown and 2 three-fourths grown, stupefied; and 4 one-half grown and 2 three-fourths grown, active. These 10-year-old trees were all treated in the spring (April 4 and 5) with the 1-ounce dose of paradichlorobenzene, and exposed to the gas for a period of 6 weeks. The borer mortality from this spring treatment was 88.2 per cent. There were 51 live borers in the 7 untreated trees.

The data given in Table 3 show that during the season of 1922–23 the fall applications were in most instances fatal to the peach borer, even when as low as one-half ounce was used for only three weeks. Many of the trees that were treated with the ¼-ounce and 1-ounce doses were not examined for borer mortality, as tests with these doses the previous year gave conclusive evidence that they were effective for borer control. The chief observations were made on the effect of different doses of paradichlorobenzene on peach trees of various ages, particularly those under 8 years of age, and how they reacted to different periods of exposure to the gas. The results obtained from the experiments revealed that the season was favorable for the use of paradichlorobenzene. Not a single tree of any age died from the treatment that season. Three examinations for tree injury were made in the fall, spring, and summer, the final examination showing no injury to 1, 2, 4, 5, 7, and 10 year old trees. Except in the case of one tree in the 2-year-old orchard, the injury to the 2-year-old trees was confined to flecking of the bark layers (Fig. 4). The spring applications caused no tree injury in 1923, and gave a borer mortality of 89.2 per cent.

1923-24 EXPERIMENTS

Peach trees ranging in age from 1 to 7 years were used for the paradichlorobenzene experiments during the 1923–24 season. Unrefined paradichlorobenzene was tested on the 7-year-old trees. Observations on borer mortality were made in the fall and spring,

and on tree injury in the fall, and the following spring and summer. Tables 3 and 4 give summaries of results of the 1923-24 paradichlorobenzene experiments. It was originally planned to allow the material to remain around trees in the 1-year and 2-year orchards for 6 weeks, and around trees in the 3-year-old orchard for 6 weeks and over winter, but as severe injury developed in the 3-year-old orchard after 4 weeks exposure to the gas, all mounds were torn down and the material removed from around the 1-year, 2-year, and 3-year-old trees after they had been exposed to the gas for 4 weeks.

At the fall examination the 1-year-old trees showed injury as follows: Flecks extending into the cambium of 5 trees exposed to a ½-ounce dose for 4 weeks; fleckings, which in one case was serious, in 4 trees exposed to a ¾-ounce dose for 4 weeks. This injury was not evident at the time of the spring examination, except on 1 tree exposed to a ¾-ounce dose, which showed a little flecking of the bark layer. No injury was found at the time of the summer examination, which was 10 months after the application. No borers were found in either the treated or untreated 1-year-old trees.

At the fall examination the 2-year-old trees showed injury as follows: Thirteen that were treated with the ½-ounce dose for 4 weeks showed flecking, two of which had the flecks extending into the cambium layer. Eleven trees treated with the ¾-ounce dose for 4 weeks had flecks in the bark layers, which in 3 trees extended into the cambium layer. The spring examination also showed flecking of the bark layers from both the ½ and ¾ ounce doses. The final examination, which was made 10 months after the application, showed 1 tree with slight flecking and 12 trees with severe flecking of the bark layers from the ½-ounce dose exposed to the trees for 4 weeks; and 2 with slight and 9 with severe flecking from the ¾-ounce dose exposed to the trees for 4 weeks. One three-fourths grown dead borer was found in the trees treated with the ½-ounce dose for 4 weeks. One live borer was found in the untreated trees.

The 3-year-old trees showed severe injury from the ½, ¾, and 1 ounce doses of paradichlorobenzene at all three of the examinations, and at the time of the final examination 11 trees had died from the ¾ and 1 ounce doses, which were exposed to the trees for 4 weeks. An examination the following fall (which was almost one year after the paradichlorobenzene was applied) for dead trees in the treated plats, showed that none had died from the ½-ounce dose, 8, or 26.7 per cent, had died from the ¾-ounce dose, and 3, or 15 per cent, had died from the 1-ounce dose. All of the control or untreated trees were alive at the time of this examination. Other trees in the treated plats showed injury but lived. The most severe injury occurred on the sunny side of the tree where the injury appeared first. (Figs. 5, 6, and 7.)

Four one-half grown, 2 three-fourths grown, and 1 more than three-fourths grown dead borers were found in the 3-year-old trees treated with the ½-ounce dose for four weeks. No borer mortality observations were made on the trees treated with the ¾ and 1 ounce doses. Twelve live borers were found in the untreated trees.

The 4-year-old trees at the fall and spring examinations showed the following: Bark flecks on 1 tree treated with a ½-ounce dose exposed for 6 weeks, bark flecks on 1 tree treated with a 1-ounce

FIG. 5.—A, Bark layers removed to show injury to the cambium of a [illegible] peach tree four weeks after treating with 1 ounce of paradichlorobenzene (fall, 1928). Note that the injury begins at a point opposite the ring of crystals and extends downward. B, bark layers removed to show injury to the cambium of a [illegible] peach tree four weeks after treating with one-half ounce of paradichlorobenzene (fall, 1928); C, bark layers removed to show condition of normal cambium of a 3-year-old peach tree in the center of untreated plot

dose for 4 weeks, and the same injury on 1 tree exposed to a 1-ounce dose over winter. At the time of the final examination only 1 tree

FIG. 6.—A, Peach trees in a 3-year-old orchard killed [illegible] applied commercially in October, 1923, and exposed four weeks to [illegible] trees in a 3-year-old orchard at Woodbury, Ga., which had each received [illegible] fourths ounce of paradichlorobenzene in October, 1923, for a [illegible]

which was exposed to a 1-ounce dose for 4 weeks, showed slight flecking of the outer bark layers. No injury was noted on the untreated trees.

A few of the 5-year-old trees showed flecks in the outer bark layers at the fall and spring examinations. At the time of the final exam-

for a four-weeks' exposure.

ination, 10 months after the paradichlorobenzene application, slight flecking of the outer bark layers was noticed in 1 tree that had been exposed to a ¾-ounce dose for 4 weeks, slight flecking of the outer

bark layers in 2 trees exposed to a 4-ounce dose for 6 weeks, and slight flecking of the outer bark layers in 1 tree, and severe flecking of the bark layers of another that had been exposed to a 4-ounce dose over winter. None of these trees were permanently injured.

None of the 6-year-old trees showed injury at any of the examinations where the paradichlorobenzene had been applied once in the fall. Where two applications were used, 1 ounce in October at the regular time and 1 ounce the following April, 2 trees showed injury to the bark layers and cambium following the second application. Observations showed borer mortality as follows: One one-half grown dead borer in trees treated with a 4-ounce dose 6 weeks later than the recommended date and allowed to remain around the trees over winter; 2 one-half grown and 2 three-fourths grown dead in trees treated April 1 and exposed to a 4-ounce dose for 6 weeks. There were 8 live borers in the 20 untreated trees.

The 7-year-old trees were treated with unsublimed paradichlorobenzene instead of the sublimed form, which is usually used. No injury to these trees was noted at any of the examinations. Observations on borer mortality were as follows: Three one-fourth grown, 4 one-half grown, 9 three-fourths grown, and 4 over three-fourths grown dead borers in the trees treated with the 4-ounce dose for 6 weeks; 1 over three-fourths grown and 3 three-fourths grown dead borers, and 1 three-fourths grown active borer in the trees treated with the 4-ounce dose and allowed to remain around the trees over winter. There were 38 active borers in the 10 untreated trees. In all probability the treated trees contained as many borers at the untreated trees at the beginning of the experiment, but many could not be found after the treatment on account of having become decomposed or disintegrated after death.

As during previous years, the results of the 1923–24 experiments with paradichlorobenzene showed that the material is a very effective larvicide when used in the fall on the recommended dates. Most of the observations that season were for tree injury, and unlike previous seasons, very severe injury developed from the use of paradichlorobenzene around young trees, particularly those 3 years of age. Table 3 shows that flecking of the bark layers occurred on trees 2 and 3 years old treated at the regular time with a ½-ounce dose for 4 weeks. No injury occurred from the use of the ½-ounce dose around 1-year-old trees. Thirteen out of twenty 2-year-old trees had the bark layers flecked from a ½-ounce dose exposed for 4 weeks, and eleven out of twenty had the bark layers flecked from a 4-week exposure of a ¾-ounce dose. The 3-year-old trees were severely injured from doses of all sizes used, and some were killed by the ¾ and 1 ounce doses after 4 weeks of exposure. The final observations for injury to the 3-year-old trees (all trees exposed to the gas for 4 weeks) showed the following: Three trees with no injury to bark layers, 2 with slight and 20 with severe bark injury, and 5 with cambium injury from the ½-ounce dose; 1 tree with no injury to bark layers, 7 with slight and 14 with severe bark injury, and 8 dead from the ¾-ounce dose; and 3 with slight and 14 with severe flecking of the bark layers and 3 dead from the 1-ounce dose. No injury of any consequence was noted on any of the treated trees that were over 3 years old.

The results of the experiments conducted during the 1923–24 season showed that the season was very unfavorable for the use of paradichlorobenzene on trees 3 years of age and younger. Conditions were unfavorable both at the time of application and during the generation of the gas, owing to abnormally high temperature and lack of moisture.

The unsublimed paradichlorobenzene used on the 7-year-old trees gave a borer mortality as follows: One hundred per cent mortality where the 1-ounce dose was used for 6 weeks, and 83 per cent mortality where the 1-ounce dose was allowed to remain around the trees over winter. No injury to the 7-year-old trees resulted from the use of the unsublimed material.

1924-25 EXPERIMENTS

During the 1924–25 season, peach trees 1, 2, 3, 4, 5, 6, and 10 years old were treated with paradichlorobenzene, either pure or mixed with sand as a filler. The applications were made either in the usual way, or the dose was placed 4 inches from the tree trunk. Observations for borer mortality were made in the fall and for tree injury in the fall and the following spring and summer. Tables 3 and 4 give summaries of results of the 1924–25 paradichlorobenzene experiments.

A considerable number of the 1, 2, and 3 year old trees showed injury at the fall and spring examinations, mostly in the form of flecks in the outer bark layers. The trees treated 2 and 4 weeks later than recommended had more serious flecking of the bark layers at these examinations than did those treated at the regular time of application.

Of the five 1-year-old trees treated with the ½-ounce dose for 4 weeks, all showed moderately flecked bark layers at the fall examination, whereas only one showed the same injury at the spring examination. Of the five 1-year-old trees treated with ½ ounce of paradichlorobenzene and ½ ounce of filler for 4 weeks, 3 showed moderately flecked bark layers at the fall examination; at the spring examination 3 showed moderate and 1 severe flecking of the bark layers. Of the five 1-year-old trees treated with the ½-ounce dose 4 inches from the trunk for 4 weeks, 2 showed slightly flecked bark layers at the fall examination, and no injury at the spring examination. Of the five 1-year-old trees treated with the ¾-ounce dose 4 inches from the trunk for 4 weeks, one showed slightly flecked bark layers at the fall examination, and no injury at the spring examination. Of the five 1-year-old trees treated 2 weeks late with the ½-ounce dose for 4 weeks, two showed severely flecked bark layers at the fall examination, and four moderate flecking of the bark layers at the spring examination. Of the five 1-year-old trees treated 2 weeks late with ¾ ounce of paradichlorobenzene and ¾ ounce of filler for 4 weeks, three showed moderately flecked bark layers at the fall examination, and no injury at the spring examination. Of the five 1-year-old trees treated 4 weeks late with the ½-ounce dose for 4 weeks, all showed moderately flecked bark layers at the fall examination, and 4 showed the same injury at the spring examination. Of the five 1-year-old trees treated 4 weeks late with the ¾-ounce dose for 4 weeks, three showed slight and one severe flecking of the bark layers at the fall examination, and two showed moderate and one severe flecking of the bark layers at the spring examination.

Injury to the 2-year-old trees at the fall and spring examinations was as follows: Three trees with bark layers moderately flecked at the fall examination, and 2 trees with the same injury at the spring examination, from the use of ½ ounce of paradichlorobenzene and ½ ounce of filler around 5 trees for 4 weeks; 1 tree with bark layers moderately flecked at the fall examination, but no injury at the spring examination, from the use of the ½-ounce dose applied 2 weeks late to 5 trees for 4 weeks; 1 tree with bark layers moderately flecked at the fall examination, but no injury at the spring examination, from the use of the ¾-ounce dose applied 2 weeks late to 5 trees for 4 weeks; all 5 trees with bark layers severely flecked at the fall examination, and 1 tree with moderate and 1 with severe flecking of the bark layers at the spring examination, from the use of the ½-ounce dose applied 4 weeks late to 5 trees for 4 weeks; and 1 tree with slight and 1 with severe flecking of the bark layers at the fall examination, and 2 trees with moderate flecking of the bark layers at the spring examination, from the use of the ¾-ounce dose applied 4 weeks late to 5 trees for 4 weeks.

Injury to the 3-year-old trees at the fall and spring examinations was as follows: One tree with bark layers moderately flecked at the fall examination, and 1 tree with very slight and 1 with moderate flecking of the bark layers in the spring, from the use of the ½-ounce dose around 5 trees for 3 weeks; 1 tree with moderately flecked bark layers at the fall examination, but no injury by spring, from the ½-ounce dose around 5 trees for 4 weeks; 1 tree with the 1923 bark layers severely flecked at the fall examination, but no injury by spring, from ¼ ounce paradichlorobenzene and ¼ ounce filler around 5 trees for 4 weeks; two trees with very slight and 1 with moderate flecking of the 1923 bark layers at the fall examination, and 1 tree with bark layers moderately flecked at the spring examination, from the use of the ½-ounce dose around 5 trees for 4 weeks; 3 trees with very slight flecking of the 1923 bark layers at the fall examination, and 2 trees with the same injury in the spring, from the use of ½ ounce paradichlorobenzene and ½ ounce filler around 5 trees for 4 weeks; 1 tree with bark layers very slightly flecked at both the fall and spring examinations, from the use of the ¾-ounce dose applied 4 inches from the trunk of 5 trees for 4 weeks; and 1 tree with bark layers moderately flecked at the fall examination, and 1 with severe flecking and portions of the cambium layer discolored at the spring examination, from the use of the ¾-ounce dose applied 2 weeks late to 5 trees for 4 weeks.

None of the trees of other ages treated during the 1924–25 season showed injury from paradichlorobenzene at the fall or spring examinations. Control, or untreated, trees were kept in each of the plats of trees of the several ages that were treated, and none of these at any time showed flecking or other injury similar to that caused by paradichlorobenzene. With the exception of a few 3-year-old trees, none of the treated trees showed any injury from paradichlorobenzene at the time of the final examination, which was made about 10 months after the material was applied.

Observations for borer mortality were made on the trees from 1 to 5 years of age and on the 10-year-old trees. Very few borers were found in trees 1 and 2 years old, as was the case during each of the years that these experiments were under way.

All of the borers found in the treated trees of the 1-year-old orchard were dead, and none were found in the untreated or control trees. All

of the borers found in the treated 2-year-old trees were dead, and 1 live borer was found in the untreated trees. In the 3-year-old orchard 75 per cent of the borers were dead and 25 per cent active where the trees were exposed to a ½-ounce dose for 4 weeks; 66.7 per cent of the borers were dead and 33.3 per cent active where the trees were exposed to a ½-ounce dose for 2 weeks; all borers were dead where the trees were exposed to a ½-ounce dose for 4 weeks; all were dead where exposed to a ¾-ounce dose for 4 weeks; 85.7 per cent were dead where the ¾-ounce dose was applied 2 weeks late and exposed for 4 weeks; all were dead where the ½-ounce dose was applied 4 weeks late and exposed for 4 weeks; all were dead where the ¾-ounce dose was applied 4 weeks late and exposed for 4 weeks; and 5 live borers were found in the untreated trees. In the 4-year-old orchard, 75 per cent of the borers were dead and 25 per cent active from the ¾-ounce dose applied at the usual time and exposed for 4 weeks; 75 per cent were dead and 25 per cent stupefied from the ¾-ounce dose applied 2 weeks late and exposed for 4 weeks; and there were 7 live borers in the untreated, or control, trees. In the 5-year-old orchard, 66.7 per cent of the borers were dead and 33.3 per cent stupefied from the ¾-ounce dose exposed for 4 weeks; all were dead from the ¾-ounce dose applied 2 weeks late and exposed for 4 weeks; and there were 13 live borers in the untreated, or control, trees. No observations for borer mortality were made in the 6-year-old orchard. In the 10-year-old orchard 93.8 per cent of the borers were dead and 6.2 per cent stupefied from the 1-ounce dose exposed for 6 weeks; all were dead from a 1-ounce dose split into two equal parts and placed at two levels for 6 weeks; 93.4 per cent were dead, 5.3 per cent stupefied, and 1.3 per cent active from a 1-ounce dose applied 2 weeks late and exposed 6 weeks; and there were 28 live borers in the 5 untreated trees. The borers killed by the gas varied in size from under one-fourth to three-fourths grown.

The results of the 1924-25 experiments again showed that para-dichlorobenzene is very effective against the peach borer when used as recommended by the bureau to growers. The ½-ounce dose applied at the usual time, October 10 to 15, to young trees gave a borer mortality of 75 per cent. The ½-ounce dose gave a borer mortality of 100 per cent when applied to young peach trees at the usual time and allowed to remain around them for 4 weeks, but only 66.7 per cent mortality when allowed to remain 5 weeks. The ¾-ounce dose gave a mortality of from 66.7 to 100 per cent in trees under 6 years of age, but all live borers found were above the ring of crystals. The 1-ounce dose gave a borer mortality of from 93.4 to 100 per cent. All larvae in the untreated trees were alive, and the average number per tree was much higher than the number found in the treated trees. This is due to the fact that many borers can not be located in the treated trees at the time of the borer-mortality examinations on account of their having become decayed or disintegrated. At the time of the final examination, which was 10 months after the application, no tree injury was discerned from any of the doses used on any age tree when applied at the regular time and removed from 4 to 6 weeks later. A few trees in the 3-year-old orchard showed flecking of the bark layers when ½ and ¾ ounce doses were applied from 2 to 4 weeks late, and allowed to remain around the trees for 4 weeks.

1925-26 EXPERIMENTS

The paradichlorobenzene experiments of 1926-26 were conducted chiefly to check on the recommendations that were made to peach growers, although a few trees 1, 2, and 3 years old were treated for comparison with the effects of the treatments on trees of these ages during previous years. Tables 3 and 4 give summaries of results of the 1925-26 experiments. Three examinations were made for tree injury, the final one of which was made about 10 months after the application. One examination for borer mortality was made.

The results of the examinations that were made in the fall and spring for tree injury were as follows: Of the five 1-year-old trees treated with the ½-ounce dose for 4 weeks, 1 tree showed a sour spot on the sunny side at the fall examination, but no injury at the spring examination. Of the ten 2-year-old trees treated with the ½-ounce dose for 4 weeks, 1 showed slight flecking and 4 severe flecking with partial discoloration of the cambium at the fall examination and 1 showed moderate flecking and 3 severe flecking with spots in the cambium at the spring examination. Of ten 3-year-old trees treated with the ½-ounce dose for 4 weeks, 5 showed bark layers flecked with partial discoloration of the cambium at the fall examination; and 1 showed few flecks and 1 severe flecking with spots in the cambium at the spring examination. Of fifteen 4-year-old trees treated with the ¾-ounce dose for 4 weeks, 1 showed slight flecking of bark layers and 7 severe flecking and cambium discolored in spots at the fall examination; and 3 trees showed slight flecking and 7 severe flecking. Four of the latter showed spots in the cambium at the spring examination. Of the fifteen 5-year-old trees treated with the ¾-ounce dose for 4 weeks, 1 showed bark layers flecked and cambium discolored in one spot at the fall examination, but no injury at the spring examination. Of fifteen 6-year-old trees treated with the 1-ounce dose for 6 weeks, 1 showed slight flecking of the bark layers at the fall examination, but no injury at the spring examination. Of ten 7-year-old trees treated with the 1-ounce dose for 6 weeks, 2 showed flecks in the outer bark layers at the fall examination, but no injury at the spring examination.

The results of the examination for borer mortality were as follows: No borers in the treated or untreated trees, 1, 2, and 3 years old; 1 one-half grown dead borer in the treated 3-year-old trees; 2 one-half grown dead borers in the treated and 5 live borers in the untreated 4-year-old trees, and 3 one-half and 2 three-fourths grown dead borers in the treated 6-year-old trees. The 7-year-old trees were not examined for borers.

The 1925-26 results again showed that paradichlorobenzene is effective against the peach borer, since it killed all larvæ in the treated trees, although very few borers were present, especially in the younger trees. The doses used in 1926, varying in size from one-half to 1 ounce, gave complete control of the borers when allowed to remain around the trees from 4 to 6 weeks. All of the larvæ found in the control, or untreated, trees were alive, and in them the percentage of borers per tree was higher than in the treated trees. Evidently some of the borers in the treated trees could not be located on account of decomposition before the examination for borer mortality was made.

At the time of the final examination, which was made about 10 months after the application, no tree injury was observed on the 1-year-old trees from either the ¾ or ½ ounce dose exposed for 4 weeks. In both the 2 and 3 year old orchards there were 2 trees out of the 10 that showed flecks in the bark layers from the ½-ounce dose exposed for 4 weeks. In the 4 year-old orchard there were 4 trees with slight and 2 with moderately severe flecks in the bark layers out of 15 trees that were exposed for 4 weeks to a ¾-ounce dose. At the time of the final examination no injury was found on the 5-year-old trees treated with the ¾-ounce dose for 4 weeks, or on the 6 and 7 year old trees treated with the 1-ounce dose for 5 weeks. All of the check trees were normal throughout the experiment.

LABORATORY EXPERIMENTS WITH PARADICHLOROBENZENE, 1921–1925

1921–22 EXPERIMENTS

The 1921–22 laboratory work with paradichlorobenzene was reported upon in detail in a previous publication.[7] The chief points revealed as a result of these studies were that paradichlorobenzene will kill peach-borer larvae as far down as 1 foot below the soil surface when the gas is controlled by confinement in battery jars; that the gas is liberated at about the same rate in both sandy loam and clay soils; and that the lower the temperature and the higher the moisture content of the soil, the slower is the evaporation of the crystals and the action of the resultant gas on the borers.

1922–23 EXPERIMENTS

The laboratory experiments conducted during the 1922–23 season were on the rate of evaporation of paradichlorobenzene under various conditions of temperature, moisture, depth of soil, and quantity used. Experiments were also conducted on the rate of mortality of peach-borer larvae exposed to paradichlorobenzene under varying temperature and moisture conditions. All cage experiments were conducted in the laboratory yard and subjected to normal orchard conditions, except the cages that were artificially moistened with known quantities of water.

Table 5 gives a summary of the results obtained on the rate of evaporation of paradichlorobenzene crystals.

[7] See footnote 4, p. 1.

TABLE 5.—*Rate of evaporation of paradichlorobenzene crystals in outdoor cages at the laboratory, Fort Valley, Ga., as tests started October 10, 1922*

| Depth of crystals below soil surface | Size of dose | Amount of moisture added | Evaporation (average number of days required for treatment to disappear as the result of the action of the prevailing weather conditions) | | |

TABLE 6.—*Mortality of pea-aphid larvae reared under varying conditions of soil moisture, time of application, depth below crop, and kinds of sulphur to parasitic enhancement, Pond Valley, Oreg., 1927–28*

Table 6 shows that all larvae were killed in 7 to 17 days when placed from 6 to 10 inches below the rug of crystals. A 1-ounce dose under normal conditions killed all larvae 6 inches below the crystals in 7 days. Smaller doses, such as one-half ounce, required somewhat longer to kill, as it did in those cages to which water was added. However, all cages, except the control, gave a 100 per cent mortality within 17 days. No larvae died in the control, or untreated, cages.

When peachborer larvae are placed on peach bark in soil cages at 8 to 10 inches below the paradichlorobenzene crystals they generally feed to some extent before they become stupefied by the gas, especially when water is added to the cages at the beginning of the experiment. If the larvae can burrow into the bark and conceal themselves, they will live longer than those remaining on the surface of the bark. The larvae used in the experiments were all about one-half grown. A correlation of the results of these experiments with field conditions indicates that newly hatched larvae just entering the bark tissues at about the time of the application of paradichlorobenzene would all be killed.

The gas in the test cages generated very slowly during the 1922-23 season, but borer mortality in them was rapid in spite of the cool and damp weather. It would appear that a very small amount of the gas is required in a container to kill the insect.

1923-24 EXPERIMENTS

During the 1923-24 season experiments were conducted to determine the rate of evaporation of the several different sizes of paradichlorobenzene at different durations of exposure, such as were recommended to the peach growers for use in commercial orchards. Table 7 gives the results of these experiments. The containers for the gas were either 6 by 8 inch battery jars with bottoms not removed, or mounds of soil such as are used around peach trees after the paradichlorobenzene is applied. The paradichlorobenzene was placed 4 inches down in the soil in the battery jars, and in the case of the soil mounds, such as are used in orchards, the chemical was placed on the soil surface and then covered with soil to a depth of 4 inches.

TABLE 7.—*Rate of evaporation of different doses of paradichlorobenzene at different durations of exposure, Fort Valley, Ga., 1923-24*

Date applied	Size of dose	Evaporation expressed in percentage of initial weight of paradichlorobenzene—			Time required for [illegible]	Amount of moisture added	Type of container
		5-7 weeks	9-11 weeks	15-18 weeks			
	Ounces				*Weeks*		
Oct. 9, 1923	½	43.6	....			None	Battery jar.
Do	½	46.1	...			0.1 weekly	Do.
Do	½	28.9	...			0.2 weekly	Do.
Do	¾	.....		32.0	..	None	Do.
Do	¾	.....		27.4	....	0.1 weekly	Do.
Do	¾	.....		23.5	....	0.2 weekly	Do.
Do	1	93.6	97.3	100.0	6	None	Duplication of field mounds.
Do	1	74.4	91.4	98.1	16	....do	Do.
Do	1	73.1	77.2	82.4	27½	do	Do.

The data given in Table 7 show that, under normal orchard conditions, about 6 weeks are required for complete evaporation of the ½-ounce dose and 16 weeks and 27½ weeks, respectively, for complete evaporation of the ¼ and 1 ounce doses. In each case the material was applied on the usual recommended date. The data given in Table 7 also show that the addition of water to the soil retards the generation of the gas.

1924-25 EXPERIMENTS

During the 1924–25 season experiments were conducted to determine how far above the ring of crystals the paradichlorobenzene gas is effective in killing peach borers. Two types of cages were used for these experiments. The first six were 0 to 8 inch battery jars with the bottoms removed and sunk into the soil to a depth of about 4 inches. The last six were merely soil mounds, the paradichlorobenzene being placed in the ground and the larvae placed at specified distances above the chemical in a mound similar to that used when applying the material around peach trees in an orchard. The borers were dug out of peach trees on the day the experiments were started. Fresh orchard soil was used in all the cages, and five larvae per cage were placed in the soil at the indicated distance above the ring of crystals. The larvae, which were all about one-half grown, were supplied with fresh peach bark for food. One ounce of paradichlorobenzene was placed in each cage, except one control, or untreated, cage, in which no crystals were used. All cages were placed in the open without tops and during a part of the day were subjected to direct sun rays. Table 8 gives the results of these experiments.

TABLE 8.—*Mortality of peach-borer larvae at different distances above [illegible] containing 1 ounce doses of paradichlorobenzene, Fort Valley, Ga., 1924*

Cage No.	Date	Distance above crystals (inches)	Condition of larvae: Dead	Stupefied	Active	Duration of exposure (days)	Percentage killed	Soil temperature: Maximum (°F.)	Minimum (°F.)	Remarks
1	Nov. 4	[illegible]	6	1	0	7	80	81	46	Larvae did no feeding. Dead ones turned black Oct. 23. Strong odor of paradichlorobenzene at lower level. 47 grains had evaporated by Oct. 30 when cage was closed.
		[illegible]	7	0	0	14	100	71	49	
2	do	[illegible]	3	2	0	7	60	81	46	Larvae did no feeding. Strong odor at lower level. 39 grains evaporated in 21 days.
		[illegible]	1	1	0	14	80	71	49	
		[illegible]	1	0	0	21	100	75	51	
3	do	[illegible]	3	2	0	7	60	81	46	Larvae fed a little before death. Strong odor at lower level. 33 grains evaporated in 21 days.
		[illegible]	1	1	0	14	80	71	49	
4	do	[illegible]	1	3	1	7	20	81	46	Larvae did some feeding. Mild odor at lower level. Only 2 larvae found. [illegible]
		[illegible]	3	1	0	14	40	71	49	
5	do	[illegible]	5	1	1	7	40	81	46	[illegible] had escaped by Oct. 29. Mild odor at lower level. 26 grains evaporated in 14 days.
		[illegible]	2	0	0	14	40	71	49	
6	Control	Nov. 4	0	0	5	.....	.....	76	51	Larvae did considerable feeding, 3 burrowing into bark until they were out of sight.
7	Nov. 4	Nov. 11	2	3	0	7	40	76	52	Larvae did a little feeding. Strong odor at lower level. [illegible] grains evaporated in 21 days.
		Nov. 18	1	4	0	14	80	72	49	
8	do	Nov. 11	2	4	1	7	80	76	52	[illegible]
		Nov. 18	3							
9	do	Nov. 11	3	2	1	2	7	40	76	52	Fairly strong odor at lower level. Larvae did some feeding. 91 grains evaporated in 21 days.
		Nov. 18	3	2	1	0	14	80	72	49
		Nov. 25	3	1	0	0	21	100	63	38
10	do	Nov. 11	4	1	0	4	7	20	76	52	Larvae fed considerably. [illegible] at lower level. 4 larvae had escaped by Nov. 20. 98 grains evaporated in 21 days.
		Nov. 18	1	0	4	5	.....	.....	72	49
		Nov. 25	4	.....	.....	.....	.....	.....	63	38
11	do	Nov. 11	1	2	1	2	7	20	76	52	Larvae fed considerably. Strong odor at lower level. 3 larvae escaped by Nov. 20. 96 grains evaporated in 21 days.
		Nov. 18	5	1	0	3	14	40	72	49
		Nov. 25	5	.....	.....	.....	(1)	.....	63	38
12	Control	Nov. 25		0	0	5	.....	.....	63	38	Larvae fed considerably.

[1] Four escaped.

[2] Three escaped.

Table 8 indicates that the 1-ounce dose of paradichlorobenzene is effective in killing peach-borer larvae up to 3 inches above the ring of crystals when the material is exposed to them for at least 3 weeks, and partially effective in killing them up to 5 inches above the crystals. All of the larvae used in the experiment were killed within 3 weeks, except those that escaped and those in the untreated cages, which remained healthy and active throughout the experiment.

SPECIAL EXPERIMENTS WITH PARADICHLOROBENZENE

RATE OF EVAPORATION

Special experimentation was under way during the 1924–25 and 1925–26 seasons to determine the sum of hour-degrees of temperature (above 55° F.) necessary to evaporate the ½, ¾, and 1 ounce doses of paradichlorobenzene under prevailing quantities of precipitation for those seasons. Narrow, loosely woven cloth sacks (fig. 8, A) were made to contain the dose of paradichlorobenzene crystals; three

A
B

were placed around the trees (fig. 8, B) and covered with soil mounds similar to those of the regular treatments. Each week sacks containing the three different doses were removed from around the trees and weighed in grams, the loss in weight between dates representing the actual evaporation of paradichlorobenzene for the week. The

FIG. 9.—Soil thermograph placed in the experimental orchard for use in connection with vapor evaporation studies

sum of hour-degrees above 55° Fahrenheit required for the amount of evaporation each week was obtained from a soil thermograph which was set up in the orchard where the experiments were being conducted. (Fig. 9.) Data on tree injury and borer mortality were taken each week when the sacks of crystals were removed.

Table 9 gives the results of these special paradichlorobenzene experiments for the two seasons.

TABLE 9.—*Results of special tests to determine the sum of hour-degrees of temperature (above 55° F.) necessary to evaporate 3 percent doses of paradichlorobenzene under prevailing weather conditions; Fort Valley, Ga., 1924, 25 and 1925–26*

ONE-HALF OUNCE DOSE (219 GRAINS)

Tree No.	Length of exposure	Condition of trees		Number and condition of borers		Evaporation		Sum of hour-degrees above 55° F.		Precipitation	
		1924	1925	1924	1925	1924	1925	1924	1925	1924	1925
	Days					*Grains*	*Grains*			*Inches*	*Inches*
1		No injury	No injury	1 stupified	No borers						
2	14	do	do	1 dead	do						
3	21	do	do	No borers	do						
4	28	do	do	do	do						
5	35	do	do	do	do						
6	42	do	do	do	do						
7	49	do	Bark layers flecked. Parts of cambium discolored	do	1 dead						
8	56	do	Bark layers flecked. Cambium discolored on south and east sides.	do	No borers						
9	63	do	Outer bark layers flecked. Cambium unimpaired	1 dead	do						
10	70	do	No injury	No borers	1 dead						
Total		do	7 trees injured	100 per cent dead after two weeks	100 per cent dead						

THREE-FOURTHS OUNCE DOSE (328 GRAINS)

1	7	No injury	No injury	No borers	1 dead						
2	14	do	do	1 dead	No borers						
3	21	do	do	No borers	do						
4	28	do	Bark layers scattered flecked. Cambium discolored on southeast side.	1 active above ring	do						
5	35	do	Bark layers and cambium flecked on north and west sides.	do	do						
6	42	do	Bark layers and cambium flecked and spotted	No borers	do						
7	49	do	No injury	do	1 dead						
8	56	do	Slight shrinking of bark layers. Cambium unimpaired.	do	do						
9	63	do	Outer bark layers flecked on both north and south sides of tree.	do	No borers						
10	70	do	No injury	do	do						
Total		do	5 trees injured	100 per cent dead below ring	100 per cent dead						

EFFECT OF CUTTING BORE HOLES

No.	No. borers	Dead borers	Live borers
1	4	4	0
2	4	4	0
3	4	4	0
4	4	4	0
Borers in bark layers and cambium on trees.			
5	4	4	0
Borers in bark layers on trees after removal of outer bark layers.			
6	4	4	0
7	4	4	0
8	4	4	0
Borers in bark layers on trees after removal of bark layers on northwest side.			
9	4	4	0
10	4	4	0
Total	40	40	0
Mulched plats; borers feeding on outer bark layers.			
4 trees treated	16	16	0
Total trees	56	56	0
Average per tree	5.6	5.6	0
Not injured by the borers	10 trees	10 trees	

[1] Only thirty days after the recommended time of application for these plats.
[2] Examined June 15, the date examined by standard [illegible] Weather protection was poor.
[3] All examined at the end of 45 days.

Table 9 shows that the rate of evaporation was much faster in 1924 than in 1925 on account of the higher soil temperature during the generation of gas and the lower precipitation. However, no tree injury was observed in 1924, whereas in 1925 all sizes of doses produced injury, in some cases severely flecking the bark layers and discoloring portions of the cambium layer. It is believed that the injury in 1925 was due largely to an accumulation of gas near the tree as a result of the large amount of precipitation which prevented the normal diffusion of the gas through the soil. Borer mortality, from all sizes of doses used in these special experiments, was excellent during both years, all borers being killed within the recommended period of exposure to the gas. The control, or untreated, trees that were maintained both years showed no tree injury or borer mortality.

When calculated for the entire period, twenty hour-degrees above 55° F. were required to evaporate each grain of the ½-ounce dose in 1924, as compared with 19.9 in 1925; 15.6 hour-degrees were required to evaporate each grain of the ¾-ounce dose in 1924, as compared with 16.9 in 1925; and 15.5 hour-degrees were required to evaporate each grain of the 1-ounce dose in 1924, as compared with 14.4 in 1925. This gives a variation of from 14.4 to 20.0 hour-degrees above 55° F. required to evaporate one grain of paradichlorobenzene. When calculated for weekly periods the variation in the number of hour-degrees above 55° F. required to evaporate one grain of paradichlorobenzene is much greater, ranging from 10.4 to 37.3 calculated on the basis of the first week. Therefore no direct correlation was found between the sum of hour-degrees above 55° F. and the quantity of paradichlorobenzene evaporated.

RELATION OF SOIL TEMPERATURE AND RAINFALL TO BORER MORTALITY AND TREE INJURY

Figure 10 is a graphic presentation of the biweekly mean soil temperature during the period from the recommended time of paradichlorobenzene application until 10 weeks later, for the period 1922 to 1925, inclusive. In 1922 and 1923 the soil temperature was taken with a hand soil thermometer. In 1924 and 1925 the soil temperature was recorded by a soil thermograph set up in the orchard so that the temperatures recorded would correspond to those at the ring of crystals after it was covered with the soil mound.

The rainfall during the 10-week period following the recommended time of paradichlorobenzene application in 1922 to 1925, inclusive, is shown graphically in Figure 11.

A comparison of the two graphs shows that normal soil temperature and rainfall occurred in 1922 during the period of the generation of the gas, which in Georgia is not more than six weeks. There was no tree injury from paradichlorobenzene in 1922. In 1923, high soil temperature and low rainfall occurred during the period of the generation of the gas, resulting in severe tree injury, and killing some of the 3-year-old trees treated with ¾ and 1 ounce doses. In 1924, normal soil temperature with low rainfall occurred during the period of gas generation, and there was no tree injury. In 1925, low soil temperature with abnormally high rainfall occurred during the period of gas

generation, resulting in severe injury to some trees from all sizes of doses used. From these data it would appear that high soil temperature accompanied by low rainfall, or low soil temperature accompanied by high rainfall, will cause paradichlorobenzene to injure young peach trees in Georgia. The high soil temperature with a precipitation deficiency is apparently the most dangerous weather condition for the use of paradichlorobenzene crystals onaccount of the possibility of tree injury from the rapid generation of the gas. Data on this phase of the work were obtained from results of regular orchard applications in 1922 and 1923, and from results of special controlled orchard tests in 1924 and 1925.

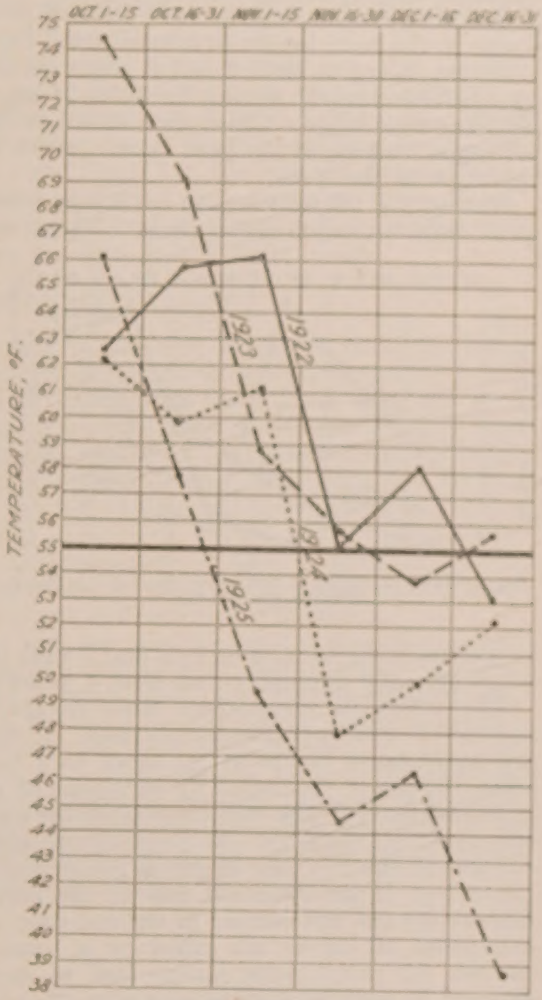

FIG. 10.—Biweekly mean soil temperature at Fort Valley, Ga., Oct. 1 to Dec. 31, 1922, 1923, 1924, and 1925. The heavy horizontal line indicates the lowest soil temperature for effective results with paradichlorobenzene

SUMMARY AND CONCLUSIONS

Life-history studies showed that most of the peach-borer moths emerge in Georgia during September. Gas for peach-borer control is most effective at the close of the oviposition period of the moths.

Orthodichlorobenzene, paratoluidine, and calcium cyanide were tested for peach-borer control, but none of them were as safe and effective as paradichlorobenzene.

Paradichlorobenzene was used on the same trees in one orchard for five consecutive years with no discernible tree injury and resulted in almost complete eradication of the peach borers.

Poor results were obtained with large doses of paradichlorobenzene for short exposures, and only fair results with small doses applied at the regular time for long exposures. The ¾ and 1 ounce doses exposed to the trees for from four to six weeks gave excellent borer control.

Paradichlorobenzene applied in central Georgia at the usual time (October 10 to 15) gave a higher borer mortality than when applied two, four, and six weeks later. Spring applications were not as effective as those made in the fall.

No tree injury of any consequence developed from the use of paradichlorobenzene during the 1921–22 and 1922–23 seasons, only a few flecks in the bark layers of several trees being noted.

Severe injury to trees 2 and 3 years old developed from the use of paradichlorobenzene during the 1923–24 season. Some of the 3-year-old trees were killed. Older trees were not injured that season, except for slight flecking of the bark layers, which apparently did not affect the vigor of the trees.

During the 1924–25 season no injury resulted to 1 and 2 year old trees from paradichlorobenzene. There was flecking of the bark layers of a few 3-year-old trees, but no injury to any of the older trees.

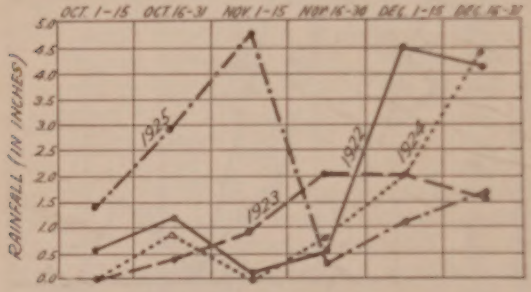

FIG. 11.—Biweekly rainfall at Fort Valley, Ga., Oct. 1 to Dec. 31, 1922, 1923, 1924, and 1925

In 1925–26 there was no injury to the 1-year-old trees, the bark layers of trees 2, 3, and 4 years old were flecked, and there was no injury to the older trees.

Five years of experimentation with paradichlorobenzene in the Georgia peach belt showed that it is unsafe to use for borer control on 1, 2, and 3 year old peach trees; and safe, when properly applied, on all trees 4 years of age and older.

The following conclusions were reached as a result of experimentation with paradichlorobenzene in the laboratory: (1) It will kill peach-borer larvae as far down as 1 foot below the soil surface when the gas is controlled by confinement in battery jars; (2) there is no difference in the effectiveness of the gas in the different types of soil used; (3) the lower the temperature and the higher the moisture content of the soil, the slower is the evaporation of the crystals and the action of the resultant gas on the borers; (4) under some conditions the gas will remain in the soil over winter; (5) under normal conditions all larvae are killed by a 1-ounce dose within a 17-day period; (6) peach-borer larvae feed to some extent after they are exposed to paradichlorobenzene gas; (7) when applied at the recommended time under normal orchard conditions, complete evaporation of the ½-ounce dose usually takes place within 6 weeks, the ¾-ounce dose within 16 weeks, and the 1-ounce dose within 27½ weeks; and (8) borers 3 inches above and occasionally those 5 inches above the ring of crystals are killed by the gas.

Special studies under orchard conditions to determine the sum of hour-degrees above 55° F. necessary to evaporate different doses of paradichlorobenzene showed that there was no direct correlation between the hour-degrees and the amount evaporated. While the rate of evaporation was slower in 1925 than in 1924, heavy precip-

itation prevented the normal diffusion of the gas through the soil, concentrating the gas near the tree and producing more or less injury to young trees. Even 4-year-old trees were injured to some extent by paradichlorobenzene under the weather conditions following paradichlorobenzene applications in 1925. Borer mortality from the doses used in these special studies was excellent, all borers being killed within the recommended period of exposure.

Evidently high soil temperature accompanied by low rainfall or low soil temperature accompanied by high rainfall will cause paradichlorobenzene to injure young peach trees in Georgia. High soil temperature and a concurrent precipitation deficiency were the most dangerous weather conditions for the use of paradichlorobenzene that were encountered during the course of these experiments, on account of the rapid generation of gas, which caused very severe injury to peach trees younger than 4 years of age.

RECOMMENDATIONS

Paradichlorobenzene should be applied to peach trees for borer control as follows: Remove grass, stones, and trash for about a foot out from the tree trunk and smooth the soil surface with the back of a shovel; then place the paradichlorobenzene crystals in a continuous band about 1½ inches wide and 1½ inches from the trunk and cover carefully with a shovelful of clean soil; then add several more shovelfuls and pack the soil around the tree to form a mound. The ring of crystals should always be placed above the topmost borer gallery, and if there are indications of borers above the normal level of the soil it should be raised so that the crystals can be placed above the point where the borer indications are observed.

For trees 4 and 5 years old use the ¾-ounce dose per tree, and remove mounds and unspent crystals after four weeks' exposure. For all older trees use the 1-ounce dose, and remove mounds and unspent crystals after six weeks' exposure. The material should not be used on 1, 2, and 3 year old trees in the South.

Paradichlorobenzene should be applied in central Georgia between October 10 and 15; in northern Gerogia between September 25 and October 5; and in southern Georgia between October 15 and October 20. The same dates should be used for applying the material in similar latitudes of other Southern States.

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